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A Review on Topologies for Wireless Power Transmission application for Electric Vehicles

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ABSTRACT: Wireless power transfer (WPT) using magnetic resonance is the technology which could set human free from the annoying wires. In fact, the WPT adopts the same basic theory which has already been developed for at least 30 years with the term inductive power transfer. WPT technology is developing rapidly in recent years. At kilowatts power level, the transfer distance increases from several millimeters to several hundred millimeters with a grid to load efficiency above 90%. The advances make the WPT very attractive to the electric vehicle (EV) charging applications in both stationary and dynamic charging scenarios. This paper reviewed the technologies in the WPT area applicable to EV wireless charging. By introducing WPT in EVs, the obstacles of charging time, range, and cost can be easily mitigated. Battery technology is no longer relevant in the mass market penetration of EVs. It is hoped that researchers could be encouraged by the state-of-the-art achievements, and push forward the further development of WPT as well as the expansion of EV.

KEYWORDS: Dynamic charging, electric vehicle (EV), inductive power transfer (IPT), safety guidelines, stationary charging, wireless power transfer (WPT).

I.INTRODUCTION

We can charge the battery using two methods they are wired and wireless. Inductive charging, also known as wireless charging, has found much successes and is now receiving increasing attention by virtue of its simplicity and efficiency.The most important distinctive structural difference between contactless transformers and conventional transformers is that the two „coils" in the former are separated by a large air gap. Compared with plug and socket (i.e., conductive) charging, the primary advantage of the inductive charging approach is that the system can work with no exposed conductors, no interlocks and no connectors, allowing the system to work with far lower risk of electric shock hazards. As the charging system is often fully enclosed, wireless charging can be realized in waterproof packages and as such, wireless charging is rechargeable devices need to be frequently used near or even under water as well as in humid conditions. Broad application of wireless inductive-coupled contactless energy transfer systems is stymied by their fast-declining efficiency performance as a function of wireless relative energy transfer distance. This relative measure is defined as the actual energy transfer distance divided by the radius of the wireless inductive energy transfer system. However, recent improvements in semiconductor technology provide an opportunity to almost gratuitously improve on

the system efficiency, because a higher operating frequency, in general, benefits the inductive energy transfer.Applications, e.g., wireless charging of electrical vehicles by means of a magnetic coil in the road surface, thus become feasible and slowly become ready for a market introduction. The success of this program may prove to be a very significant step forward towards the possibility of unlimited range electric mobility. By extending the range of electric vehicles, this project will contribute to overcoming a critical limitation of existing electrical vehicles, by offering range at competitive costs. Physical separation between the primary and secondary windings incurs proximity-effect winding losses.

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II. MEHODOLOGY

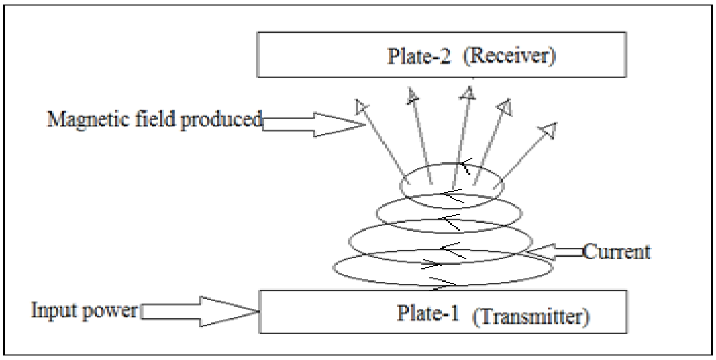

FIG 1: GENERAL DIAGRAM OF TRANSMITTING AND RECEIVING PLATE

There has been a widespread research on wireless power transmission in the previous decade. It can be categorised into radiative and non-radiative on the basis of energy transfer mechanisms. Radiative power is transmitted through an antenna in the form of an electromagnetic wave. But since electromagnetic waves travel in all direction, the energy efficiency is low.[5,6] Non-radiative power is based on the magnetic coupling of the conducting loops. Non-radiative power transmission can be further divided into short range and mid range where the mid range WPT means transmission distance is greater than the resonating coil's dimensions.

The three basic aspects of WPT are:
1. Inductive coupling between working and driving circuits.
2. Tuning in of circuits, that is "oscillation transformer".
3. Capacitance loaded open circuit.

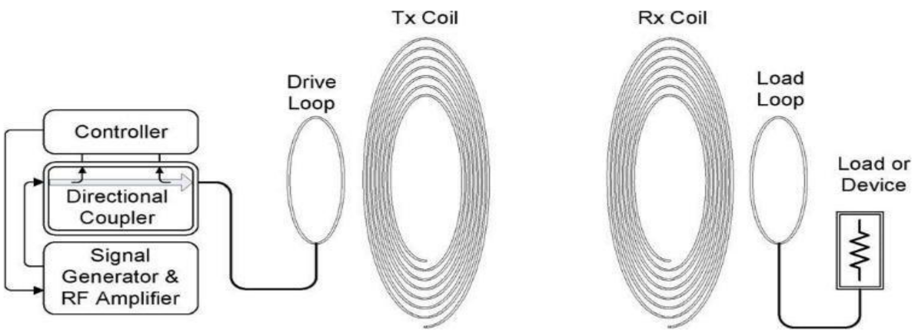

Fig 2: MAGNETICALLY COUPLED WPT SYSTEM

The Tx coil gets excited due to the magnetic oscillating field produced by the RF amplifier which gives power to the drive loop. The Tx coil is a multiturn spiral coil next to the single turn drive loop. This system acts as a step up transformer. On the receiving side the similar arrangement now acts as a step down transformer due to the single turn load loop connected to the device. The Tx coil and the Rx coil share mutual inductance which is a function of the distance between them and their geometry. Power can be transmitted through large air gaps when the transmitting and

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the receiving coil is in resonance and have the same resonant frequency. The further approach and description through which transmissions can take place are:

2.1 Coupling Theory:

This technology is based on the working principle of mutual inductance via a two part transformer such that change in current flow through one winding induces a voltage across the ends of the other winding through electromagnetic induction, as shown in Fig. 5. The inductive coupling between two conductors.

2.1.1 Winding Structures:

The shape size and location of the magnetic core becomes important due to absence of metal-metal contact and hence windings play an important role in an efficient power transfer. Recent development in magnetic circuits for coupling on-vehicle pads to ground based pads at higher efficiency have improved significantly. New polarized pads have been developed and exhibit superior performance when compared to earlier pads developed.

2.2 Inductive WPT:

Inductive power transfer (IPT) has been used successfully in several EV systems such as the GM EV1. The magne aka the primary is the charging paddle and the secondary are embedded in epoxy. The charging paddle is inserted in the centre of the secondary coil which begins the charging of the EV1 without any contacts or connectors at either 6.6 kW or at 50 kW. This system is connector-less but is not wireless. An universal IPT system using 10 kVA coaxial winding transformer for a 6.6 kW, 77 kHz, 200/400 V EV charger is presented in Fig 6 [8]. By utilizing a coaxial winding transformer benefits the ability to relocate all transformer core material off-board, and minimizes the sensitivity of on-board EV components to flux density and frequency. By using this method, transformer makes it feasible to implement a single loop, which can operate over wide frequency range and the ability to scale up to meet different power requirements. The design of the core of the transformer concerns over the impact of non-linear flux distribution which results in losses like eddy current losses and electromagnetic interferences. The losses mentioned above are dependent on the core size, increasing when the transformer is scaled up.

2.3 Capacitive WPT:

Recent technological venture of capacitive wireless power transfer has been proposed as an alternate contactless power transfer solution. The structure is same to the fig(5) , with the CPT interface between a pair of coupling capacitors. Other parts such as the inverter and rectifier structures remains same. Since magnetics do not scale down as desired with decreasing power, at some power level. The cost and size of the galvanic isolation components can be minimized with a capacitive interface.[8] However, this solution is not preferred in High Power applications. And because of this most of the existing CPT solutions are applied in low power applications and portable electronic devices such as wireless tooth brush chargers, or wireless cellular phone chargers where the power transfer interface is implemented with capacitive coupled matrix pads.

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Technology	Efficiency	Performance	Frequency	Cost	Size/Volume	Complexity Of System	Suggested Power Level
Inductive Power Transfer (IPT)	Medium	Medium	10–50 Khz 100–500	Medium	Medium	Medium	Medium/ High
Capacitive Power Transfer (CPT)	Low	Medium	Khz	Low	Low	Medium	Low
Permanent Magnet Coupling Power Transfer (PMPT)	Low	High	100–500 Hz 1–20 Mhz	High	High	High	Medium/ Low
Resonant Inductive Power Transfer (RIPT)	Medium	Low	10–50 Khz	Medium	Medium	Medium	Medium/ Low
On-Line Inductive Power Transfer (OLPT)	Medium	Medium	100–500	High	High	Medium	High
Resonant Antennae Power Transfer (RAPT)	Medium	Medium	Khz	Medium	Medium	Medium	Medium/ Low

Roadway /Online Power Transfer:

Online Power Transfer system has a similar concept to that of roadway power transfer. However, in the latter case a lower resonant frequency is used and in the OPT applications at high power levels can be done. In this case the primary coil is spread out over an area on the roadway and within this area the power transfer takes place.

Typically, the combination of the input side of the resonant converter and the distributed primary windings collectively is known as the trackand the secondary coil is known as the pickup coil, which is in the vehicle. The system is supplied by a three phase AC system, or high voltage DC system.

The Online Electric Vehicle (OLEV) developed by the Korea Advanced Institute of Science and Technology (KAIST) is an innovative transportation system. In 2010, it ranked amongst the top 50 innovations in the TIME magazine. The KAIST OLEV uses the conversion of 60Hz frequency to 200kHz using an inverter which makes 200A of current flow through it with up to 80% efficiency transmitted wirelessly. When a vehicle is operating on a road with power transmitters installed in it, the power transmitter collects electricity from underneath the ground and distributes it either to the motor or the battery depending on the requirement as shown in the figure 4. If there are no power transmitters then the OLEV runs on the battery. Hence this technology enables the OLEV to be mobile during charging.[14]
If the short range of the EVs and the associated cost of infrastructure is considered, the feasibility of these charging system might be unfavorable. However, one benefit is that due to frequent and convenient charging, vehicles can be manufactured with a minimal battery capacity (about 20% compared to that of the conventional batterypowered EVs), which can consequently minimize the weight and the price of the vehicle. A charger with narrow rail width, 10 cm, and

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large air-gap, up to 20 cm, was proposed. An efficiency of 74% was reported at 27 kW output power for a threephase supply input of 440 V, and 20 kHz switching frequency.

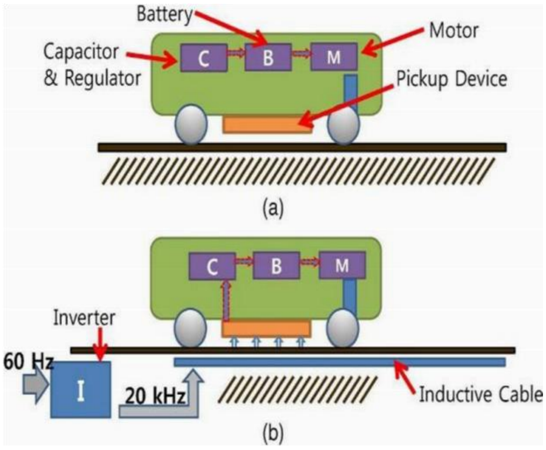

Fig. 3: (a) WPT without transmitters (b) WPT with transmitters[14]

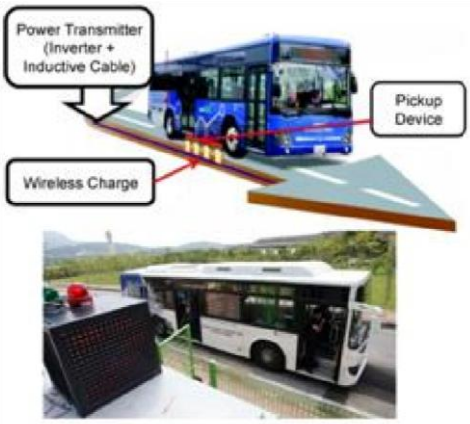

Fig. 4: A prototype OLEV in KAIST campus[14]

In comparison to pure battery EV and battery replace EV , Hybrid EV , Plug-in hybrid EV and Roadway power EVs do not require innovations in battery for commercialization; as in these EVs can be readily available in markets using currently affordable EV batteries. When the power supply rails for transmitting power to RPEV are fully deployed under the road , RPEVs need not require battery energy storage for their traction because they directly get required power from the road while they are moving on it.

Hence, RPEVs are most free from the battery-related problems among EVs and quite promising for future transportation of small cars, passenger cars, taxies, buses, trams, trucks, trailers, and trains, even in competition with internal Combustion engines.

Despite the fact that RPEVs are free from battery problems, RPEVs are not being widely used. The drawback of this technological solution is the high power transfer from the road efficiently, within the bounds of economic status and safely. The power transfer is either wired or wireless. Earlier, the former method was preferred because of no advancement in wireless power transfer. The highest speed train is powered through pantographs, which are a sort of wired power transfer device. Because of the wearing of pantographs and due to the maintenance problems, wired power transfer is gradually replaced with wireless one as hundreds of kilowatts of power become available. Thus, various wireless power transfer systems (WPTSs) have been widely developed for RPEVs.

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Important technical issues in the developments of inductive power transfer systems (IPTSs), the majority of WPTSs, are addressed, and major milestones of the developments of RPEVs are summarized, focusing on the developments of on-line electric vehicles (OLEVs) that have been recently commercialized.

2.7.2 Fundamentals of WPTS for RPEV:

Overall Configuration of the WPTS: The requirement for WPTS in RPEVs is that a high power should be efficiently delivered via a moderate air gap to avoid collisions between the RPEVs and the road. The WPTS are composed of two subsystems:

1) Roadway subsystem for providing power, which includes a rectifier, highfrequency (HF) inverter, primary capacitor bank, and power supply rail.
2) On-board subsystem for receiving power, which includes a pick-up coil, secondary capacitor bank, rectifier, and regulator for battery, as shown in the fig(9) [15]

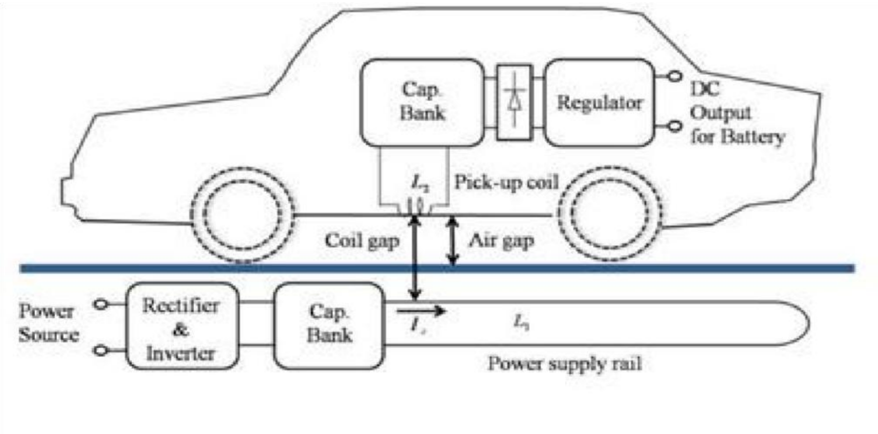

Fig 5 : Roadway powered electric vehicle.

III. OVERVIEW

Wireless power transfer is a generic term for a number of different technologies for transmitting energy by means of electromagnetic fields. The technologies, listed in the table below, differ in the distance over which they can transfer power efficiently, whether the transmitter must be aimed (directed) at the receiver, and in the type of electromagnetic energy they use: time varying electric fields, magnetic fields, radio waves, microwaves, infrared or visible light waves.

In general a wireless power system consists of a "transmitter" device connected to a source of power such as a mains power line, which converts the power to a time-varying electromagnetic field, and one or more "receiver" devices which receive the power and convert it back to DC or AC electric current which is used by an electrical load. At the transmitter the input power is converted to an oscillating electromagnetic field by some type of "antenna" device. The word "antenna" is used loosely here; it may be a coil of wire which generates a magnetic field, a metal plate which generates an electric field, an antenna which radiates radio waves, or a laser which generates light. A similar antenna or coupling device at the receiver converts the oscillating fields to an electric current. An important parameter that determines the type of waves is the frequency, which determines the wavelength.

Wireless power uses the same fields and waves as wireless communication devices like radio another familiar technology that involves electrical energy transmitted without wires by electromagnetic fields, used in cell phones, radio and television broadcasting, and Wi-Fi. In radio communication the goal is the transmission of information, so the amount of power reaching the receiver is not so important, as long as it is sufficient that the information can be received intelligibly. In wireless communication technologies only tiny amounts of power reach the

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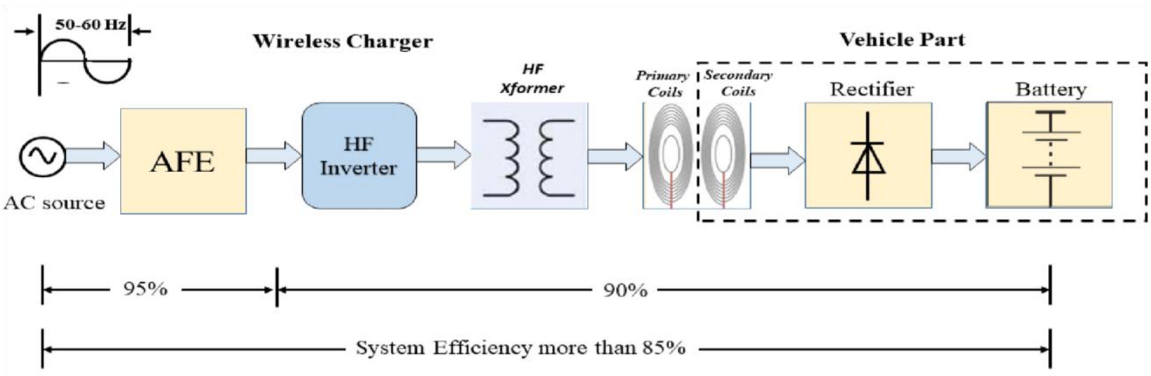
receiver. In contrast, with wireless power transfer the amount of energy received is the important thing, so the efficiency (fraction of transmitted energy that is received) is the more significant parameter. For this reason, wireless power technologies are likely to be more limited by distance than wireless communication technologies.



- **FIG 6 :BLOCK DIAGRAM OF A WIRELESS CHARGING SYSTEM**

IV. CHALLENGES

- The most prominent drawback of all WPT systems is the fact that low efficiency energy is transferred. Most of the losses takes place during the energy transfer from coil to coil.
- Furthermore, installation cost of WPT charging systems will be more than plug-in charging methods due to many factors, which includes but is not limited to, increased infrastructure, goods and safety/shielding requirements. Hence, WPT might be disadvantageous to EV consumers as it is not cost effective.

V. CONCLUSION

In this article we reviewed the different technological solutions for WPT, their limitations and different applications. It also includes the advances made in the field such as RPEV, OLEV and SPS. RPEV and OLEV are still used at a lower scale and SPS will be fully functional by 2040. There has been a lot of research on short range power transmission but research is still going on to limit the losses in mid range power transmission. Hence, WPT will lead the world to an advanced, greener and a sustainable future.

REFERENCES

[1] Li, S., & Mi, C. C. (2014). Wireless power transfer for electric vehicle applications. IEEE journal of emerging and selected topics in power electronics, 3(1), 4-17.
[2] Ahmad, A., Alam, M. S., & Chabaan, R. (2017). A comprehensive review of wireless charging technologies for electric vehicles. IEEE Transactions on Transportation Electrification, 4(1), 38-63.
[3] S. L. Ho, Junhua Wang, W. N. Fu, and Mingui Sun Department of Electrical Engineering, The Hong Kong Polytechnic University, "A Comparative Study Between Novel WiTricity and Traditional Inductive Magnetic Coupling in Wireless Charging", IEEE
[4] TRANSACTIONS ON MAGNETICS, VOL. 47, NO. 5, MAY 2011Deng, J., Li, W., Nguyen, T. D., Li, S., & Mi, C. C. (2015). Compact and efficient bipolar coupler for wireless power chargers: Design and analysis. IEEE Transactions on Power Electronics, 30(11), 6130-6140.
[5] Bi, Z., Kan, T., Mi, C. C., Zhang, Y., Zhao, Z., & Keoleian, G. A. (2016). A review of wireless power transfer for electric vehicles: Prospects to enhance sustainable mobility. Applied Energy, 179, 413-425.
[6] Zhou, S., & Mi, C. C. (2015). Multi-paralleled LCC reactive power compensation networks and their tuning method for electric vehicle dynamic wireless charging. IEEE Transactions on Industrial Electronics, 63(10), 6546-6556.
[7] Li, W., Zhao, H., Deng, J., Li, S., & Mi, C. C. (2015). Comparison study on SS and double-sided LCC compensation topologies for EV/PHEV wireless chargers. IEEE Transactions on Vehicular Technology, 65(6), 4429-4439.
[8] M Maqsood and N Nauman Nasir, Wireless electricity (Power) transmission using solar based power satellite technology, Journal of Physics, 2013
[9] Fariborz Musavi, Wilson Eberle, Overview of wireless power transfer technologies for electric vehicle battery charging, IET Power Electronics, 2013
[10] Sanghoon Cheon, Yong-Hae Kim, Seung-Youl Kang, Myung Lae Lee, JongMoo Lee, and Taehyoung Zyung, Circuit-Model-Based Analysis of a Wireless Energy-Transfer System via Coupled Magnetic Resonances, IEEE Transactions on Industrial Electronics, Volume: 58, Issue: 7, July 2011